KNOWLEDGE-BASED ENGINEERING IN CONSTRUCTION: THE PREFABRICATED TIMBER HOUSING CASE

SUBMITTED: November 2007
REVISED: August 2008
PUBLISHED: September 2008
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SUMMARY: *Swedish prefabricators of domestic buildings need to become more effective and efficient; the aim of this paper is to investigate the usefulness of rule-based IT support tools for this purpose. The current sales and design process at a timber volume element prefabricator is presented and evaluated regarding information management and standardisation. It was found that information management during early design is often ad hoc and person dependent; therefore searching for information that could lead to reuse of past solutions is rather time demanding. There is a need for standardisation due to a mentality of designing one-of-a-kind buildings. Knowledge-based engineering is seen as an enabler to enhance the current situation and an IT support procedure is suggested. A demonstrator stair tool was tested, which lets the seller discuss needs with the customer and then use the tool to assess cost and manufacturability. It is argued that the IT support procedure can enable; automation of activities and availability of down stream knowledge in virtual format and a connection between instances of the same geometry. If design flaws can be found early on, downstream waste activities can be reduced. Standardisation could be realised through modularisation, which the implementation of the IT support tool procedure could gain from.*

KEYWORDS: *Timber prefabrication, information management, knowledge-based engineering, early phase design, manufacturing evaluation*

1. INTRODUCTION

The Swedish house building industry needs to increase its effectiveness (doing the right things) and efficiency (doing things right). Timber volume element (TVE) prefabricators have focused on how to minimize time spent at the construction site and prefabricate as much as possible in the factory, but production is still handicraft-based and the organisation is more function-oriented than process-oriented (Höök 2005). Design is usually project-based, where building systems are developed in a way that makes reuse of earlier solutions difficult. Hence, construction researchers have begun to look at methods developed within the manufacturing industry (Gann 1996). IT support is seen as an enabler of effectiveness and efficiency, even though the company organisation has to be robust to gain positive results (Wheelwright and Clark 1992). Johnsson (2006) described IT support used at TVE fabricators in Sweden, and found issues are among others, a low level of use of virtual models. The use of enterprise-resource planning software to integrate company functions in a business system, e.g. to enable better sales support, is common in the manufacturing industry, though it is not extensively used by Swedish TVE prefabricators (Bergström and Stehn 2005). Knowledge-based engineering (KBE), where the geometry engine of computer aided design (CAD) software is coupled to a rule base for automatic product configuration and evaluation, has become more and more popular in recent decades (Chapman and Pinfold 1999; Rosenfeld 1995). KBE has, however, not been extensively tested within the TVE prefabrication industry or even the construction industry. The aim of this paper is to investigate the usefulness of rule-based IT tools for information management and standardisation by surveying the early design process at a TVE prefabricator.

2. LITERATURE REVIEW

2.1 Knowledge-based engineering

There is a trend that construction research is looking to adopt methods from the engineering industry (Gann 1996). One method originating from the manufacturing industry is knowledge-based engineering (KBE), which according to Rosenfeld, (1995), was first coined at the launch of the CAD-software ICAD in 1984. KBE is a method to enhance engineering design by creating design support tools based on a CAD-environment. By capturing and formalising knowledge into rules, routine and time demanding work can be automated and engineering knowledge can be made available in the CAD-environment. KBE enables parameterisation of topologies; a simple example is a cylinder that can swiftly be transformed into a rectangular prism governed by sets of rules. Engineering knowledge can be made available to evaluate the impact of design on, for example, manufacturing operations, assembly and maintenance. By doing so, cost estimations and warning messages can be generated as a result of design changes. Because design activities are automated, KBE represents a way of capturing design processes. KBE software often have an object oriented structure, where geometry is created and evaluated in terms of classes containing stored rules, and a geometry engine that manages and visualises the geometry. Chapman and Pinfold (1999) claim that KBE can promote organisation of the information flow and create rapid design solutions where more ideas and scenarios can be evaluated than without KBE. Examples of KBE applications are within aerospace (Isaksson 2003) and automotive (Chapman and Pinfold 2001). Isaksson (2003) claims that KBE can enable the use of information from later processes in early design, though the KBE application may be quite intricate to organise within the virtual modelling environment, i.e. CAD, product-data and product life-cycle management systems. Chapman and Pinfold (2001) argue that KBE can be used to automate the pre-processing stages of structure analysis. KBE is often used to support engineering design decisions, by enabling synthesis and analysis faster than done manually, rather than excelling the knowledge of the engineering designers. KBE can however reduce the loss of experience during staff turnover as information and knowledge can be stored in the product model.

2.2 Industrialised house-building

Lessing (2006) p.179, assumes industrialisation as a key issue for the house-building industry and further defines industrialised house-building as:

"Industrialised house-building is a thoroughly developed building process with a well-suited organization for efficient management, preparation and control of the included activities, flows, resources and results for which highly developed components are used in order to create maximum customer value."

For several decades, detached houses for one to two families have been built more or less industrially, where volume elements of completely prefabricated rooms occur. Elements for multi-storey buildings have also been prefabricated industrially, e.g. concrete walls. Fig. 1 shows a view of industrialised house-building that means reducing on-site construction and increasing factory prefabrication.

2.3 IT support for industrialised house-building

Together with organizational changes computers can enable enhancements of the industrialised house-building industry (Olofsson et al. 2004). In their investigation, Olofsson et al. state that the greatest potential for integration of computer product models is for specialised companies, such as timber volume element (TVE) prefabricators. To become a successful TVE prefabricator, customisation and flexibility issues have to be overcome (Höök 2005) and addressed in the product models. Johnsson (2006) has documented information technology currently used at some TVE prefabricators in Sweden. Examples of found issues are lack of information management strategy, low level of use of virtual models for documentation, and lack of integration between virtual construction tools and Enterprise Resource Planning (ERP) systems. According to Bergström and Stehn (2005), there is a low use of ERP systems in the industrialised timber industry. This low use is argued to depend on the complexity of the business process. Crowley (1998) states that computers cannot solve every problem, rather the market is the driving force.

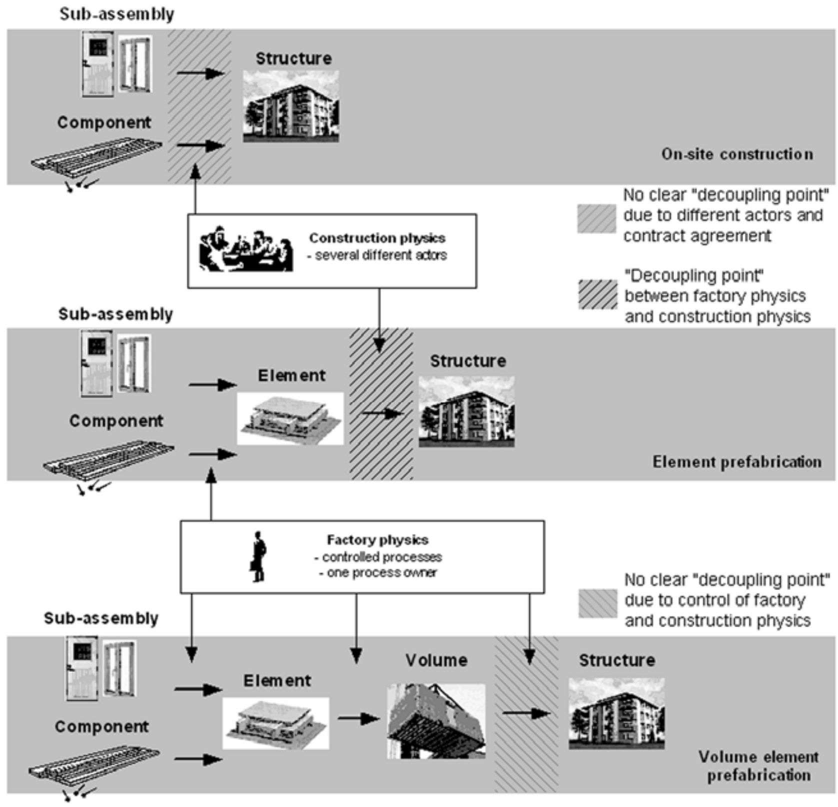

Figure 1. One view of industrialised building, from (Höök and Stehn 2005) .

2.4 KBE in construction

Work for rule-based construction can be found. Gross (1996) describes a rule-based program for building construction kits where the program controls the placement of house object according to a number of grids. Gross argues that creativity is still possible although rules constrain the positioning as compared to kids playing with Lego™ and having seemingly unlimited possibilities to create new innovative constructions. Ganeshan et al. (1996) present an object-oriented CAD system that is integrated with a rule-base to allow for cost and time evaluation of construction design alternatives. It is argued that using the tool designers can get feedback earlier on than usually. Xuejun et al. (1990) presents a system that automatically plans house layouts. It is a combinatorial problem that is handled with artificial intelligence and provides full automation i.e. lesser interaction than the other work presented above. This may cause black-boxes if the automation is not understood. As seen above there are work that focus on automated design in different ways but the issue of building a rule-base that supports the design process need to be explored further.

3. CASE STUDY

3.1 Research approach

A case study at a Swedish TVE prefabricating company, a small and medium sized enterprise (SME), was performed. The company's process from *customer and supplier negotiations and early design* to *on-site assembly*, where used software was included, were mapped before this study and further refined during an open focused group discussion. Company representatives from management, market, design and production functions participated in the discussion, which was recorded and analysed as a qualitative interview. The reason for discussing, e.g. preparation and production, is because it is extremely important to evaluate manufacturability during design. After the mapping discussion, a group discussion on the topic of information management and standardisation during design was conducted. The group discussion followed the future workshop model (Kensing and Madsen 1991), which is intended for participative software development and has the phases critique, fantasy and realisation. The critique phase focuses on experienced issues and problems, the fantasy phase on ideas if resources are unlimited and the realisation phase on realistic ideas. Four people from the company holding the positions local manager, production manager, seller and design manager participated in the mapping discussion and the workshop. Separate semi-structured interviews were conducted after the workshop to gain further information on the topic from the workshop with two other building designers and two layout architects, e.g. kitchen furnishing. Most interviews were recorded, while some informal interview were summarised afterwards in text.

Stair and joist frames are used as limited examples, yet having sales, design and production connection, to show the research ideas in a demonstrator. This demonstrator can be used to discuss overarching implications such as when using IT support of the kind being exemplified. Conclusions can be drawn by discussing issues of supporting whole house design.

3.2 Company introduction

The company develops and produces houses, e.g. multi-storey buildings and detached houses for dwellings and schools, and sheds for construction workers using industrialised timber volume element prefabrication. Turnover is approximately €40M with around 300 employees. The company has four production units in Sweden, one of which this study was conducted at. Fig. 2 shows an overview of a timber volume prefabrication process.

Figure 2. Timber volume prefabrication.

3.3 Findings

3.3.1 Process

The company does not have an explicit process map of their workflow. Some engineering designers say they work *"from the beginning to the end"*, indicating that they think the process is obvious and thus not necessary to describe.

Fig. 3 shows the process phases on a time axis to give an understanding of the time proportions, while Fig. 4 presents the first phase, *customer and supplier negotiations and early design*. The dark shaded activities are of interest for the suggested IT support tool. Each output document from an activity is connected to the software it was created in. Involved in this phase are customers, sellers, designers and sometimes production and purchase staff.

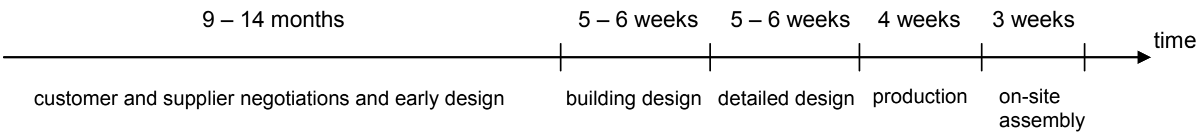

Figure 3. Process phases on a time axis.

Manufacturability evaluation during design, done during check off meetings, is mainly based on experience. No tool or documented method for manufacturability evaluation was presented. Design flaws found and corrected during production are not always updated in the latest drawing because, according to the production manager, they make one-of-a-kind houses and a certain house will probably not be produced again. *"Once, we made the same house again, but then the first house took fire and was destroyed."* So a one-of-a-kind mentality exists among the employees even though the houses have similarities, e.g. geometrical.

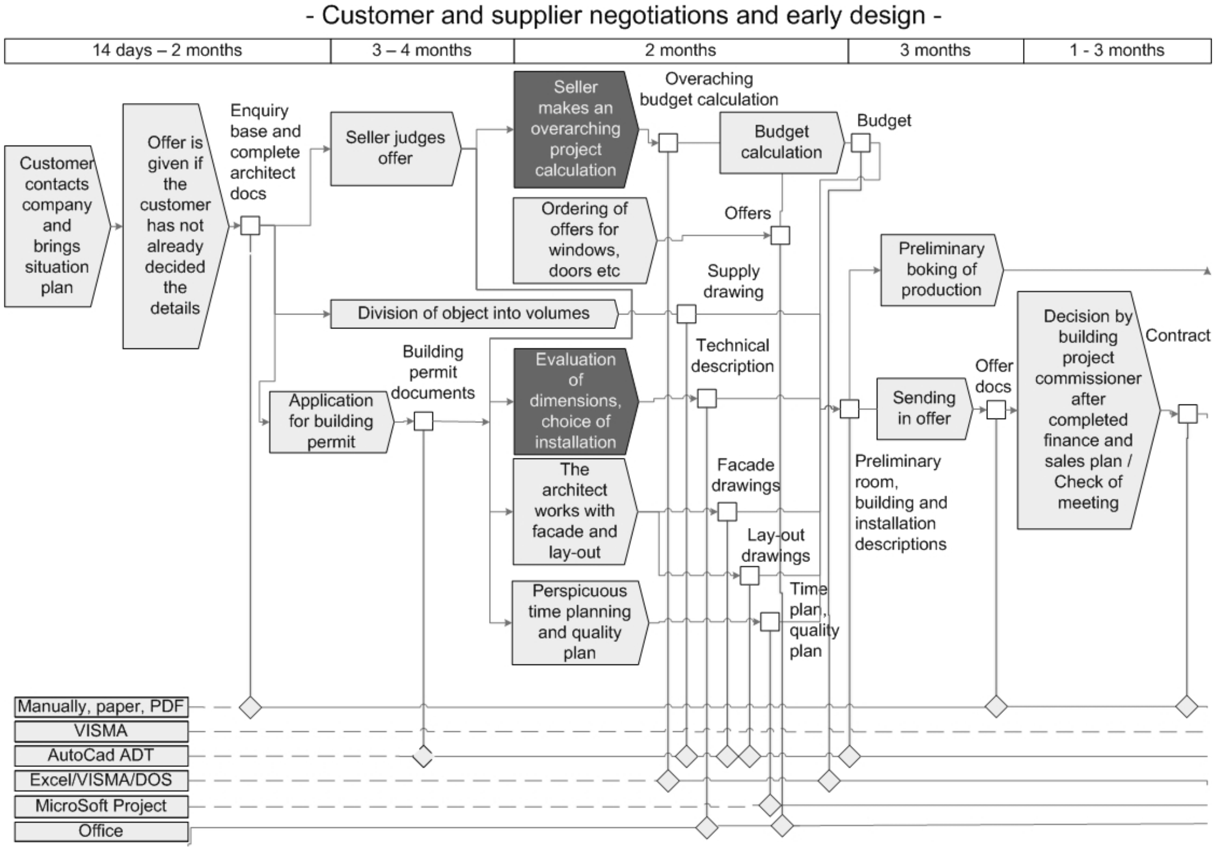

Figure 4. The customer and supplier negotiations and early design phase.

3.3.2 Information management

The company lacks an overall information strategy and much information is only available on printouts or through personal memory or in a non-accessible format that is only understood by the one who wrote it, i.e. the rationale or context is missing. Some software is claimed to be time demanding to use because of a lack of integration with other software. One example is a custom made program for economic calculations, where manual work becomes time demanding due to the lack of integration with an in-house component database. The level of integration between the CAD-software (AutoCad ADT™) and the ERP system (VISMA™) is also low. CAD-models are not parametric and design work has characteristics of time demanding routine work, e.g. sometimes the same feature is drawn multiple times in the same model without connection to the other features. This implies that each part has to be redesigned separately at a design change. One designer has stated the difficulty in reusing CAD-objects, as the outer dimensions always change from project to project. However, in-house architects reuse kitchen objects during kitchen design. Knowledge and information transfer usually takes place by working together in the same room. It is possible to find printouts from earlier projects and finding documents if a project is remembered, e.g. knowing the project number and the house details considered interesting for the new project. No database exists with the possibility to automatically search for documents of earlier project. Salespersons quite often have to search for information, usually in document folders containing printouts from earlier projects. Therefore, finding information that can be reused becomes time demanding and there is a risk for efforts being made on solving an already resolved design task.

3.3.3 Standardisation

Standardisation during design is not evident. Finding a standard for the building system is difficult because the interviewees claim that every order is a one-of-a-kind and will not be used again. When discussing product platforms, one interviewee regarding every joist frame as one platform. It is, however, expressed that having a low number of building elements that can be used by the customer to define the framework design for the house would be beneficial. A team, with staff from sales, design and production, has however been formed recently to work with standardisation. The objective for this team is to focus on standardising solutions for corners and walls and other parts that not are supposed to be affected be the opinion of the customer. Standardised parts are then stored in a database which everyone has access to. There also exist certain platform houses, but there are different opinions of what a platform house is. Some see platform houses as houses where change what-so-ever is prohibited while others accept variation to some degree.

4. SUGGESTION OF IT SUPPORT TOOL PROCEDURE

4.1 Chosen scenario

Stairs are a crucial component in buildings and a possible module to standardise. Therefore, stairs were chosen as an example to demonstrate a sell and design support tool (SDST) in a virtual construction environment. The company uses a stair design program, but the program does not enable automatic updating of geometry affected by new stair configurations. The following current process was detailed during the workshop and chosen to be supported by the SDST:

1. The customer creates an idea together with an external architect, and based on this idea the seller and the customer have agreed upon a house layout.
2. The seller suggests a U-stair, which is the standard stair that can save space, but the customer wants to know what the house will cost if a straight or a turning stair is chosen.
3. The seller goes back to the company and investigates how the house layout and choice of stairs affect the cost by consulting earlier project documents and company staff, if possible, and calculates the cost for each stair choice.
4. When the cost is calculated the customer and seller meet again and the customer can decide which stair to choose.

4.2 IT support tool functionality

The idea is to automate and support parts of activities 2 and 3; see section 4.1. Fig. 5 shows an outline of a GUI for the demonstrator IT support tool. During activity 2, the type of stair can be varied (U, round and straight) and how the joist frame of the house is affected can be assessed. With the IT support it is possible to conduct activity 2 with the customer, since the assessment is partly automated. Stair placement in the layout plan can be varied to change the entrance to the upper floor. It is also possible to change the joist configuration in terms of extra stiffening beams, and automate this activity by implementing equations for mechanics of the materials. If the placement of the stair or the joist configuration is not feasible, i.e. not possible in terms of stiffness or to manufacture, a warning message is generated and suggestions for changes are given. Views can be changed to show the layout more about aesthetics than engineering contents. This is exemplified in Fig. 5 top-right, as the joist frame is hidden and the floor layout is presented. The layout can be mirrored to facilitate design of terrace houses, where flats are mirrored to enable, for example, the sharing of pipes and ventilation facilities. The design activity described here can be found in Fig. 4 *Evaluation of dimensions, choice of installation*, though the choice of installation is beyond the scope here.

The production cost is continuously calculated at every change and totalled in the interface. A cost report shows the cost components for material and work. The material cost is based on the bill of materials generated from the software where the configurator is implemented; see section 4.5. The work cost is calculated based on rules for standard production activities, e.g. the average time of producing a joist frame of this dimension. If the joist frame is configured for stiffness, then time and cost are changed for the fastening of more beams. This cost estimation activity can be found in Fig.4 *Seller makes an overarching project calculation.*

4.3 Knowledge acquisition

There are approaches to acquire knowledge as described by the MOKA consortium, where specially designed ICARE forms are used to obtain control of how knowledge is acquired and interconnected (Stokes 2001). The knowledge already acquired in this study was found by using the approach described in section 3.1. The collected knowledge can be divided into different categories, e.g. heuristics (rule-of-thumb), empirical knowledge, tacit knowledge, common sense, logic and geometrical knowledge.

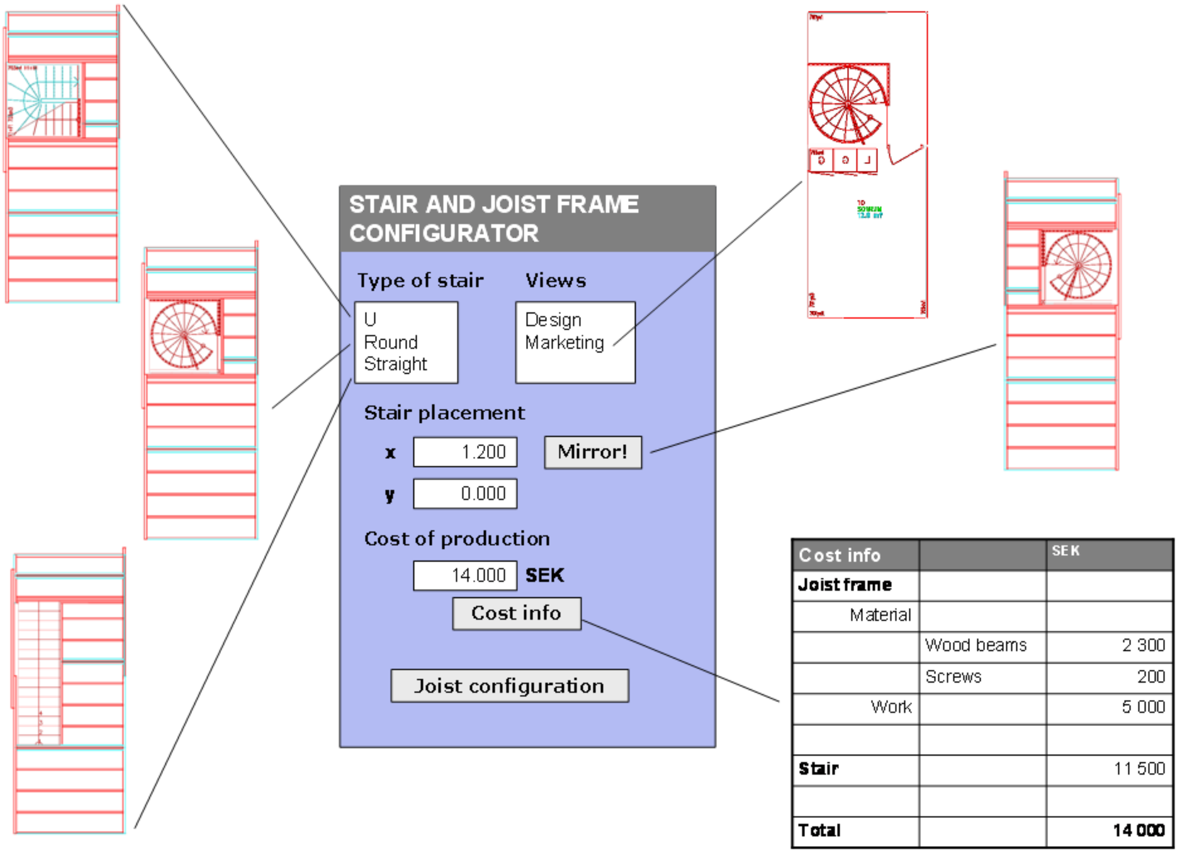

Figure 5. Outline of the stair and joist frame configurator.

4.4 Formalisation

The acquired knowledge can be formalised into a rule base that guides the automation. This means that knowledge that can be explicitly expressed as production rules, i.e. if *condition* then *action*, is most suitable for formalisation. Categories containing explicit knowledge can be, for example, geometrical, rule-of-thumb and common sense. If an object-oriented approach is used, a class division could be made where classes for synthesis and analysis are separated, since synthesis knowledge, such as design intent, tends to change more often than analysis knowledge, such as manufacturability evaluation. However, it is occasionally practical to integrate synthesis and analysis knowledge into the same class if a continuous evaluation with many detailed parameters is strived for. If an evaluation is done on a less detailed level, a class separation is more suitable. A combination could also be useful. An example of synthesis rules:

```
if stair-type = U-stair then stair-opening-overlap = 20
else stair-opening-overlap = 10;

trimmed-joist-length = stair-width + stair-opening-overlap;
```

Example of analysis rules:

```
if joist-frame-length > joist-frame-max-length
then print "It is not possible to produce lengths longer than " +
joist-frame-max-length " as the production line is not wide enough."

if stair-type = round-stair
then production-time-stair-opening = production-time-stair-opening-standard +
production-time-stair-opening-round-stair-additional
else production-time-stair-opening = production-time-stair-opening-standard
```

A class hierarchy for the SDST look as shown in Fig. 6. The class *House volume* instantiates the sub-classes *Joist frame*, *Stair* and *Cost* and theses classes in turn instantiate sub-classes.

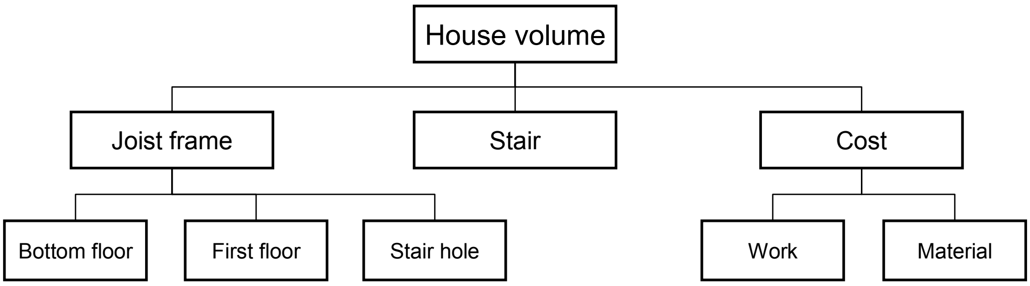

Figure 6. Class hierarchy for the SDST.

Explanation of the rules needs to be done in the code syntax to enable transparent updating.

4.5 Implementation

Implementation is done in a virtual construction software package that has possibilities for parameterisation and object oriented programming. KBE (Rosenfeld 1995) enables parameterisation of topologies along with the implementation of engineering rules for evaluation of manufacturability during design, for instance. If possible, AutoCad ADT™ should be used as software to start the implementation at the company of the SDST, making the process of starting to test the SDST easier rather than climbing the threshold implied of new software. The initial demonstrator outlined in Fig. 5 has been done in Microsoft PowerPoint™ to show the idea of automating engineering design and evaluation.

5. CHALLENGES AND OPPORTUNITIES

5.1 Process issues

A new process map, see Fig. 4, emerged from the study that differed from the original map. The process map would perhaps change again if a new group was inquired. A clear process description that the company decides to follow is needed to work effective and efficiently.

Because an IT support tool like the suggested SDST automates downstream activities, e.g. *Evaluation of dimensions, choice of installation* and *Seller makes an overarching project calculation*, it is possible to conduct these activities upstream during, for example *Offer is given if the customer has not already decided the details* activity, Fig. 4. This implies that the process is changed, as some activities can be conducted earlier. This can possibly save time as the process is automated. It however sets demands on the downstream activities to start earlier. When automated the activity is standardised and the variation of the activity output will probably be less compared to the manual activity. Therefore the people of the downstream activities will have knowledge of what input their activity will have. This can be a quality securer as standardisation decreases variation. Upstream the automation implies that more information is made available and more what-if scenarios can be conducted and this can probably help in making decisions.

5.2 Information management

Managing the information flow in a company is a vast task. This paper concentrates on how information can be readily available to sellers and designers, how routine time demanding work can be reduced by automation, and how such a system for design automation is chosen and maintained to enable successful communication. The creation of an information strategy would facilitate the work, e.g. use of virtual models and information transfer could be consequent.

5.2.1 Accessible information

It was found from the study that experience is seldom documented, but rather sustained in the memories of people and transferred to co-workers in close proximity. It is likely that the transferred knowledge is mostly explicit i.e. directly expressible instead of implicit knowledge that require more reflection to explain. Information of earlier houses can be found on printouts, but needs to also be accessible digitally. All revisions need to be stored in a digital model to avoid repeating the errors in the future. There seems to be a need for a database such as the product data management (PDM) systems found in the engineering industry to make information accessible for everyone (Johnsson 2006). Some information can only be retrieved through older software, which only a few people can handle. If the information from the older software can be obtained from a system that more people can handle, time and expense could be saved. The proposed IT support tool in section 4 could store product information about geometry configuration and engineering knowledge, e.g. manufacturability evaluation. However, the objective of the suggested IT support procedure is to help the staff make better design decisions, by delivering information in a timely manner, rather than excel the amount of knowledge that is held by the staff. This information or knowledge may not be available as the staff is busy or as it is not evident who to contact to get the information.

5.2.2 Automation

Some design work is time demanding due to unstructured work methods and an absence of functionality in the virtual construction environment. Parameterisation is a common way of automating design activities, and an extension of parameterisation is found in KBE. Through KBE, resources can be used for value-adding activities instead of time demanding routine work. Automation may also create "black-boxes", where the user does not understand what happens during the automation and therefore not trust the application. Including explanation texts in the user interface and limiting the amount of automation to mostly routine and time demanding activities in a balance of manual and automatic work might avoid the understanding problem. Simply automating more early design activities will not solve the issue of updating the virtual models when late design changes are done due to problems found during production. Since there are problems during production due to design there is currently a lack of production knowledge among the designers. A KBE tool may exceed individual designers in knowledge about production but not in the overarching knowledge of the house. However, production problems can be reduced if rules controlling the manufacturability of the geometry are implemented.

The issue of the same geometry objects not being connected might be overcome by using regular CAD tools, with assembly instance functions. Creating and following the information strategy can resolve such problems. The issue of not being able to reuse geometry due to all volumes having different outer dimensions, as one of the interviewed designers noted, could be overcome through parameterisation. KBE could also ensure quality for parts of the process being automated, as these parts will be constantly performed the same way.

5.2.3 Choice of software

The virtual construction environment is always under discussion, often regarding the drawbacks. The choice of software is not an easy matter, since there are always many needs to satisfy. The problem is often that all needs are not known when a decision is taken, but rather appear when the software is in use. Sometimes, people will ask for newer programs believing that the problems with the older software will be solved, not considering the risk that newer programs introduce new problems. Therefore, it is important to base the choice of software on needs and not technology. In this study, the issue of purchasing new and functional software versus keeping the older software that people are used to was discussed. To enable automation, AutoCad ADT™ could be exchanged for AutoCad Revit™. An alternative to using AutoCad ADT™ is to connect external software through the API (Application Programming Interface) and thus control the geometry definition process. The neutral format IFC (Industry Foundation Classes) could be used to represent the building system and gain even more flexibility in choice of software. KBE software, such as UGS NX™[1] (http://www.plm.automation.siemens.com/en_us/), is mostly found in the manufacturing industry. KBE may be less expensive for smaller companies instead of purchasing an expensive ERP package, and methods exist for KBE in SMEs (Lovett et al. 2000). However, there is also a question of integrating KBE systems with other product data management systems to avoid isolated KBE applications (Catic and Malmqvist 2007). Also, software for design of stairs, e.g. Staircon™ (http://www.staircon.com), could be used as an evaluator of stairs that are implemented in the SDST.

To provide a useful environment for product configuration, as through the SDST, there is a need for trouble free integration with other systems for geometric data and costing. As the configurator should contain rules that ensure that the building system standard is followed there is a possibility to create new articles to store in an article data base. Ultimately there would be no redundant information e.g. avoid that same information is stored both in the ERP-system as in the CAD-system. One idea is to use a database (e.g. PDM) with house articles where all other systems (CAD, VISMA, Excel etc) could extract and add information from and to the database. The connection between the systems could be automatic, semi-automatic or manual. For example, a bill of materials, from the CAD-system could automatically be sent to the cost-system (through the database) and act as a base for cost activities of the purchase department.

The PowerPoint demonstrator is currently being transferred into AutoCad ADT and the automation capabilities described in section 4 is being implemented by means of Visual Basic™.

5.2.4 Maintaining the system

Creating a successful software system specially customised for the company can be challenging, though even more challenging is keeping the system up to date with the latest knowledge and information. One way is to teach the user to program the system live, when working and new information is available. The idea of Wikis, where everyone at the company can change information on documents, is also argued to be an enabler for keeping information updated during engineering activities (Weerasinghe and Salustri 2007). A regular updating policy, e.g. once a month, could be part of the information strategy. Another approach is to create a new position, sometimes called knowledge engineer or a project information officer, as suggested by Froese (2004).

5.2.5 Whole house

The proposed IT procedure is exemplified with a stair and joist frame application which is a limited application. New challenges will be faced when extending the discussion to whole house standardisation. One challenge is to create an information structure that is transparent and maintainable as the information content is larger. There are also more people within and outside the company (e.g. architects, lead and end customers) involved in the information handling process which increase the demand of the information back bone system – the system that all digital information handling is based on. In the case of the case study company there is a need to decide upon what information back bone system to use, e.g. ERP or PDM, if aiming towards whole house models. Currently when dealing with the limit case of stairs and joist frames it is possible to have a working automation without focusing too much on the back bone system. More people also increase the demand of following the information strategy. Using a system engineering perspective may be useful where the whole house is the total system that contains subsystems in a hierarchical order.

5.3 Standardisation

A standardisation effort could provide a number of benefits. The seller could sell the “right” product from the start, i.e. a product that does not need to be changed due to problems found during e.g. production or purchase. It would be fewer question marks during design, it would probably be easier to predict purchase actions and develop collaboration with suppliers. Standardised CAD-files could be used to automatically generate lists of material to be purchased. Production could work more on routine and spend less time on reviewing drawings. Two ways to conduct standardisation is by modularisation and product platforms.

5.3.1 Modularisation

To create an IT support tool that automatically generates geometry, it is useful to conduct a modularisation to facilitate rules coding, since class division and class coding can be guided by the module network. Modular function deployment (MFD) is an approach to divide the product into modules with interfaces that allow the modules to change and still fit together (Erixon et al. 1994). MFD is suitable for products with large series, and thus motivates the cost for development of interfaces that connect the modules to each other. The interviewees perceived their products as one-of-a-kind objects, though they did not seem to share the same view of similarity between the products as the author, and conducting a modularisation effort may help the company staff to see the similarities. Because stairs are manufactured by a subcontractor, considering inter firm modularity might also be important (Staudenmayer et al. 2005). Bertelsen (2005) argues that modularisation already exists somewhat in construction and that there is a balance between efficiency and monotony if striving for further modularisation.

5.3.2 Product platforms

Another approach to standardisation is that of creating product platforms, as the company in the study also have looked at. Modularisation is one key to promote the creation of product platforms. According to Simpson (2004), there is a proactive and a reactive approach to the creation of platforms. The reactive approach seems to be for the company in the study, since its need for standardisation was identified. Most work for platforms is done for large companies but there are also tools suitable for SMEs, such as variant mode and effect analysis (Schuh and Tanner 1998). When a platform has been developed it is often more straightforward to create a rule base for automation, as the platform is defined and "only" needs to be programmed for automation.

5.4 Organisational issues

New work processes need to be defined and followed. New software needs to be learnt for proper use, e.g. ensuring a continuous updating of information. New roles may be needed, such as a project information officer. In other words, there is a need for change in company culture to trust and be able to use a support tool. Having a positive attitude to change is one enabler for success. A lack of knowledge often creates scepticism. Therefore, it is important to have a learning organisation approach (Love et al. 2000).

Value creation is one of the most important issues for companies because it is connected to the satisfaction of their customers and the success of the companies. Company core knowledge or intellectual property therefore comes into focus, which companies like to hold secret. Sometimes employees also experience an automation effort as leading to unemployment instead of minimising time demanding work. The issue of collaborating, instead of working function-oriented, could be helped by letting staff from different company divisions collaborate during regular updating of the IT support.

6. CONCLUSION

This paper presents a study at a Swedish timber volume element prefabricator, where process, information management and standardisation of the building system were evaluated. An IT support tool procedure has been suggested and discussed to overcome the found issues. It is argued that the IT support tool procedure can enable:

- Automation of activities and availability of knowledge of later activities (e.g. production and stiffness evaluation) during early activities (e.g. seller and customer negotiations), thereby changing the company process. Automation may free up time for value creating activities and reduce manufacturability problems, since design flaws can be found early on. Automation may also create an overview of parts of the company process, as activities are modelled and described for the user.
- Availability of the modelled product knowledge in virtual format instead of searching in document folders. This may decrease the time for information search. Information is, however, limited to the model.
- A connection between instances of the same geometry objects is created, such as parameterisation and a class structure for the geometry. This may free up time to attempt more solutions or conduct more evaluations.

The software needed for the implementation of the IT support procedure should have parametric possibilities and preferable object oriented capabilities. The IT support tool needs to be updated on a regular basis to have the latest information available. This updating can be part of an IT strategy. Standardisation is needed because the amount of knowledge has to be limited and well described to create the tool. To draw more exact conclusions, a complete implementation and evaluation of the suggested IT support procedure is needed. An implementation is currently being conducted.

7. ACKNOWLEDGEMENT

Funding has been provided by VINNOVA through the Centre for Lean Wood Engineering and is greatly acknowledged.

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